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Climate regionalization for main production areas of Indonesia: Case study of West Java

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Abstract. Spatially, climate condition is vary within a region and considered as essential information for planning activities such as agro-climate zonation. An approach to understand the spatial climate variability is the utilization of climate regionalization that is applied to rainfall data to distinguish differences in the pattern and magnitude (characteristics) of spatial rainfall variability over a region. Unfortunately, the application of climate regionalization poses a challenging issue in Indonesia, considering the availability of climate data. Recent advances in satellite and reanalysis data measuring climate variability over a large area provided an opportunity for the application of climate regionalization in the country. Using the West Java, one of main crop production regions in Indonesia, climate regionalization techniques were applied to map spatial variability of climate types based on rainfall data recorded by climate stations (point based analysis) and estimated by modeled/reanalysis data and satellite observations (gridded data). The regionalization derived from gridded rainfall data have reasonably better in capturing the zonal pattern of differences in climate types within the study region than the regionalization applied to insufficient numbers of site-based rainfall observation. This indicates that the gridded data offers an alternative for climate regionalization, when site-based observations are unavailable or limited.

1. Introduction

Climate is simply well-known as the average weather condition of a region in the long term period. Climate condition varies spatially over a region determined by topographical, geographical, and local condition. Climate classification is a method to identify and describe the climatic differences on a regional scale. Climate classification can be derived based on a number of factors such as rainfall, air temperature, humidity, geographical condition, and crop diversification [1]. As a tool to define differences in climate types over a region, climate classification is an essential element of regional climate information that can be used for various purposes such as agriculture, transport, and tourism.

It has been generally acknowledged that there are three climate classifications frequently employed in Indonesia, namely: Koppen, Oldeman, and Schmidth – Ferguson. Each classification technique has its own characteristics in assessment method and interpretation, which had been formulated in 1901 for Koppen [2], in 1975 for Oldeman and in 1951 for the Schmidt-Ferguson [3]. These three classification techniques required input of an essential climate-surfaced variable, i.e. rainfall, whose observations are coordinated by Badan Meteorologi, Klimatologi, dan Geofisika (Meteorology, Climatology, and Geophysics Agency) in Indonesia. The observations of rainfall are collected from rainfall or climate station over a region. Unfortunately, the limited number of stations is often being a constraint for Indonesia. Currently, available observational stations may not be sufficient to describe climate classifications for a region of interest. In this case, alternative data source to define climate characteristics of a region such as rainfall data derived from satellite, re-analysis, and models can be a good data source for employing climate classification techniques to define spatial variability of climate types over a region.

This research provides climate classification for crop production growing regions of West Java – Indonesia. The case study is selected considering West Java is one of primary crop growing regions or “food basket” in Indonesia. Defining climate types for this region can provide information on the contribution of climate types to spatial differences in crop production over the region. Concerning the limited records of site-observations, gridded climate data of WorldClim [4] and CHIRPS [5] are employed to define climate types over West Java.

2. Related works

Climate variables aproximate the patterns of climate variability over a region as the basis for climate classification. Rainfall is an essential climate variable that is often used for climate classification such as those applied by Aldrian [1] to characterize rainfall type in Indonesia. The climate classification is of interest considering it can be used for many purposes such as understanding agroclimate suitability. Previous study [6] applied climate classification to understand the suitability of climatic conditions for coconut plants, with the high production rate (~80% production target) for the region whose rainfall is about 2500-3600 mm/year. Ramala [7] defined regional suitability on the basis of irrigation, planting period, and agro-climatic zones for Cilacap. Another study, Fadholi and Supriatin [8] showed Priangan (the districs of Sukabumi, Cianjur, Sumedang, Garut, Ciamis, Tasikmalaya, and the city of Bandung) can be classified into five climate types according to Oldeman classification applied to rainfall data recorded by 41 site-observations, namely: B1, B2, C1, C2, C3. The above works demonstrated that climate classification is an essential information that also can be applied for evaluating crop-land-climate suitability over a region, understanding climate affects crop growth and development.

3. Methodology

The three climate classification method, namely: Koppen, Oldeman, and Schmidt-Ferguson, were employed to define spatial variability of climate types over West Java based on rainfall data recorded by 19-site observation stations (figure 1). In addition, climate regionalization technique developed using hierarchical clustering analysis was also applied to the site-observed monthly rainfall data to classify site-observations on the basis of statistical similatities, which is the monthly rainfall characteristic. The climate regionalization apporach was performed in several steps. First, analysis of principal component (PCA) was performed to avoid potential multicolleniarities among monthly rainfall data recorded by the site stations. The hierarchical clustering techniques were then applied to the results of PCA to group site stations with statistically similar rainfall characteristics. Several numbers of climate groups, i.e., five to nine, were used as input when perfomed the hierarchical clustering whose grouped observations based on a variety of linkage methods as discussed by Perdinan and Winkler [9]. The climate classification was also performed using gridded climate data of WorldClim for the climatologically period of 1971-2000 [4]. The main purpose is to evaluate the potential use of WorldClim as an alternative data source to define climate classification, understanding the limited availability of observation data (i.e., incomplete or unavailability of site-observations). Additionally, we also employed gridded rainfall data of CHRIPS [5], whose grid resolution is different from WorldClim to evaluate the effects of different grid resolution to regional climate classification for the study region.

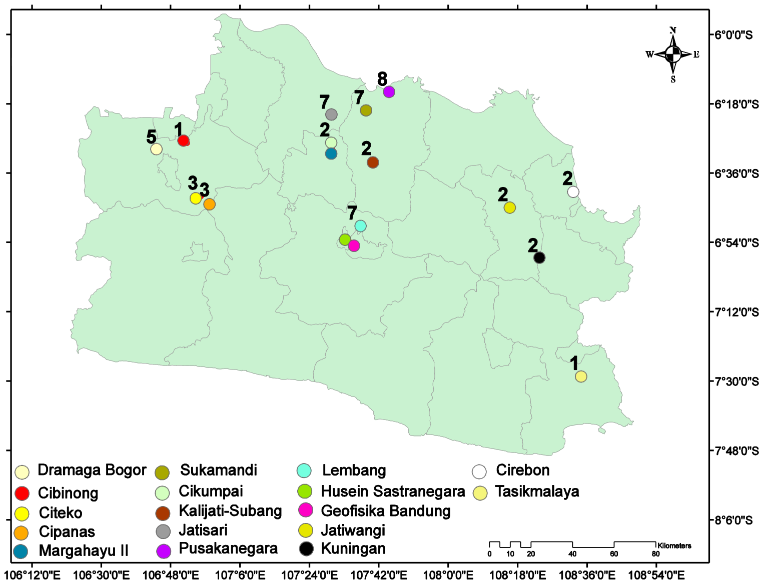

Figure 1. Location of the 19-site stations in West Java employed for the study

4. Results and discussion

The West Java Province is located between 5˚50 '- 7˚50' LS and 104˚48 '- 104˚48' E, with an area of 44354.61 km^2. West Java is directly adjacent to the Java Sea in the north, the Indian Ocean in the south, Central Java in the east, and DKI Jakarta and Banten in the west. The West Java has a monsoonal rainfall pattern. Climatologically, monthly-rainfall data of the 19-site stations (figure 1) for the period of 1950 to 2000 showed the highest rainfall amount is in January (350 mm) and the lowest rainfall is in July (97 mm), with the rainy season of November-April, and the dry season of May-October. The climate fluctuations affect the availability of water supply. For example, when the dry season is longer than normal then the needs for irrigation water also increased, which demanded for better water management strategies to storage water during the rainy season. The climate fluctuation is also influenced by global climate phenomena. Climate variability of West Java, its fluctuation and intensity, is affected by El Niño Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD). These climate phenomena cause changes in the patterns and the intensity of rainfall, such as delaying the beginning of rainy season or declining the rainfall intensity such as those reported by Apriyana and Kailaku [10] for the period of September to November in the northern West Java.

The results of climate classification derived from different classification techniques shows a little bit of variation. Based on Koppen classification, West Java had two climate types, namely: Af and Aw. The area with Af climate type is in the western part of West Java, started from Bekasi to Garut and most part of Purwakarta, Subang, Ciamis, Tasikmalaya and Depok. This climate type has considerably higher rainfall amount over the year (above 60 mm for each month). The areas with Aw are considerably drier as this climate type is indicated by longer dry season. Oldeman classified West Java into 8 climate types, namely: A, B1, B2, C2, C3, D2, D3 and D4 (figure 2). The suitable areas for paddy production are areas with A and B1 climate type. The A climate type allows for paddy to continuously grow over the year; whereas, the B1 type suggests the needs for irrigation system to continuously grow paddy particularly over the dry season. The areas with the A climate type include Bogor, Garut, and Bandung; while, the areas with the B1 climate type encompass Sukabumi, Tasikmalaya, most areas of Ciamis, Cianjur, Bekasi and Depok. Furthermore, Smith – Fergusson classifies the study region into four climate types, namely: A, B, C and D. Most areas of West Java are classified into the A climate type, which means very wet. The B, C and D climate types are shown in some parts of the north-central West Java, and covered most areas in the northern Subang and Indramayu.

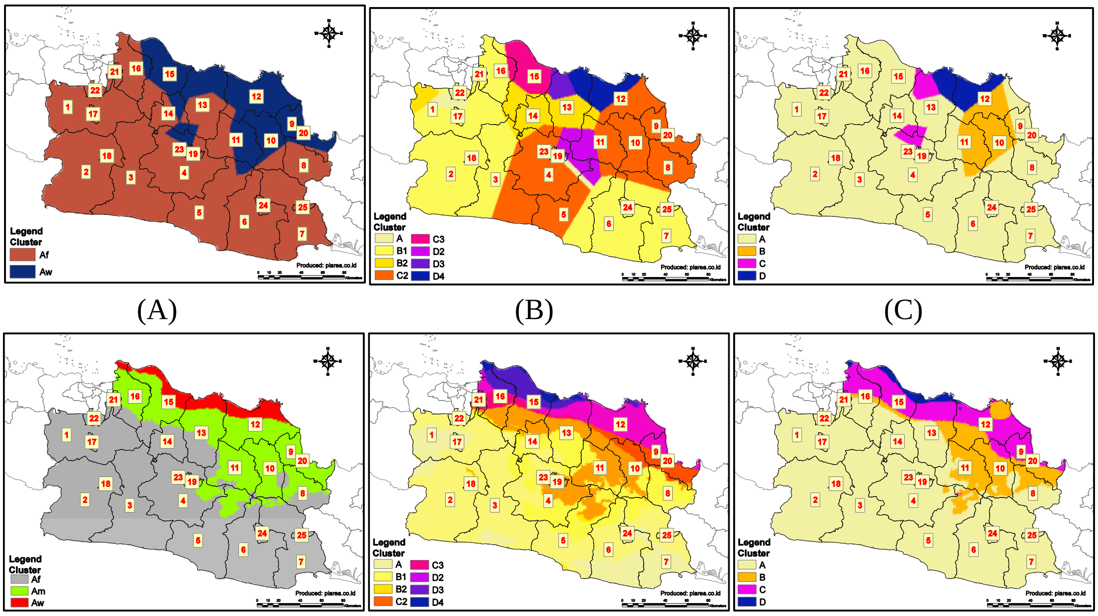

Figure 2. Climate classification for West Java developed using Koppen (a), Oldeman (b) and Smith Fergusson (c) derived from observed rainfall data (above) and WorldClim (below) of 1971-2000. The number indicates the name of district. (1) Kab. Bogor, (2) Kab. Sukabumi, (3) Kab. Cianjur, (4) Kab. Bandung, (5)Kab. Garut, (6) Kab. Tasikmalaya, (7) Kab. Ciamis, (8) Kab. Kuningan, (9) Kab. Cirebon, (10) Kab. Majalengka, (11) Kab. Sumedang, (12) Kab. Indramayu, (13) Kab. Subang, (14) Kab. Purwakarta, (15) Kab. Karawang, (16) Kab. Bekasi, (17) Kota Bogor, (18) Kota Sukabumi, (19) Kota Bandung, (20) Kota Cirebon, (21) Kota Bekasi, (22) Kota Depok, (23) Kota Cimahi, (24) Kota Tasikmalaya, (25) Kota Banjar

In addition to classifying climate types for the study region using site-observation data, the classification was also performed using grided climate data of WorldClim as an alternative of climate data source, providing insufficient availability of site-observations. The pattern of climate groups resulted from the grided climate data exhibits somewhat similar general pattern for each classification method (figure 2). The classification applied to site-observations showed more ‘rough’ climate cluster spatially, which may be the results of using insufficient numbers of site-observed stations. Meanwhile, climate classification derived from WorldClim resulted ‘smoother’ classifcation map, understanding high spatial resolution of WorldClim which gridded the study region into 43411 grids provide more detailed information for the study region. Eventually, the climate classification shows more detailed variation of climate classification map particularly in the central area of the study region, where topographical characteristics are more hilly than the nothern part of the study region. Site-observations are also very limited for the southern areas of West Java, which offer an opportunity for the utilization of gridded climate data such as WorldClim. Apart from the detailed spatial map, latitudinal pattern or zonation of rainfall classification is shown for the study region, regardless of site-observations or gridded data employed for running the classification methods.

For another comparison, climate information from BMKG which informed rainfall characteristics and the begining of rainy season supplied to distinguished climate zonation called topo (stands for Zona Musim - Seasonal Zonation) was evaluated. The ZOM supplies climate prediction for rainfall specifically for regions classified into a group, indicated by the same colors in figure 3. There are variations of rainfall conditions in the study area. The northern area includes Bekasi, Subang, Indramayu, Ciamis and Tasikmalaya, grouped into below normal rainfall. Meanwhile, the rest grouped into normal rainfall figure 3 (left).

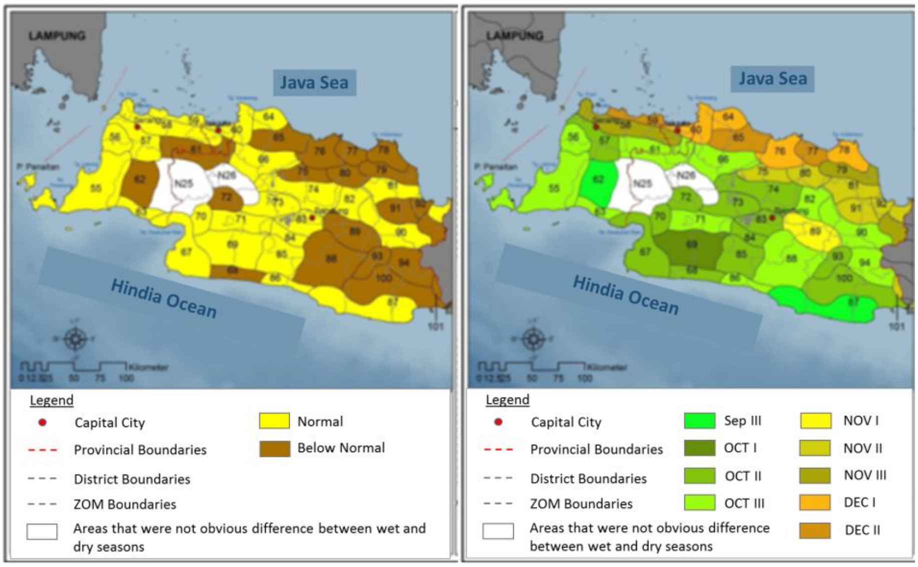

Figure 3. Climate prediction of rainfall characteristics (left) and the beginning of rainy season (right) in 2015/2016 in Banten, Jakarta and West Java (BMKG 2016)

Figure 3 (right) provides information on the climate prediction for the begining of rainy season. The district of Ciamis and Tasikmalaya were predicted to have the begining of rainy season in September; whereas, Sukabumi, Cianjur, Bogor, Cianjur and Bandung were predicted to be in October. Pangadaran, Garut, Sumedang and Majalengka would be in November. The other northern areas of West Java would have the beginning of rainy season in December. This climate information to some extend provides alternative to learn spatial variability of rainfall over the study region indicated by different pattern of the beginning of rainy season and charaterization of rainfall amount into above and below normal. However, it should be noted that the climate prediction is merely for a certain period of time, which may be different with the period of climate classification applied to climatological statistics of climate data such as rainfall over 30-year period as employed in this study.

Further analysis was conducted to classify climate types of the study region using the climate regionalization technique named hierarchical clustering analysis applied to rainfall data obtained from site-observations, WorldClim, and CHRIPS. The results showed that zonal pattern of rainfall are captured by climate regional derived from WorldClim and CHRIPS, although, WorldClim provide more detailed variation considering the higher spatial resolution of the data than the CHRIPS. The classification derived from rainfall data of site-observations provide ‘rough’ grouping, with unclear zonal pattern. Insufficient numbers of site-obsevation stations may contribute to the ‘rough’ patterns of the climate classification. Interestingly, the climate regionalization derived using gridded datasets (figure 4-middle and below) can almost imitate the zonal pattern of Oldeman classification (figure 2-middle). Evaluation of the zonal pattern explains that the southern and central parts of the study region exhibit high spatial variation for the climate groups derived from WorldClim and CHRIPS. This indicates that the gridded datasets have reasonably captured the variation of topography in the study region.

Further analysis was applied to evaluate rainfall characteristics of climate groups derived from the hierarchical clustering technique using rainfall data of site-observations. The evaluation was performed based on monthly rainfall fluctuation over a year for each station grouped into a specific climate type as presented in table 1 and figure 5.

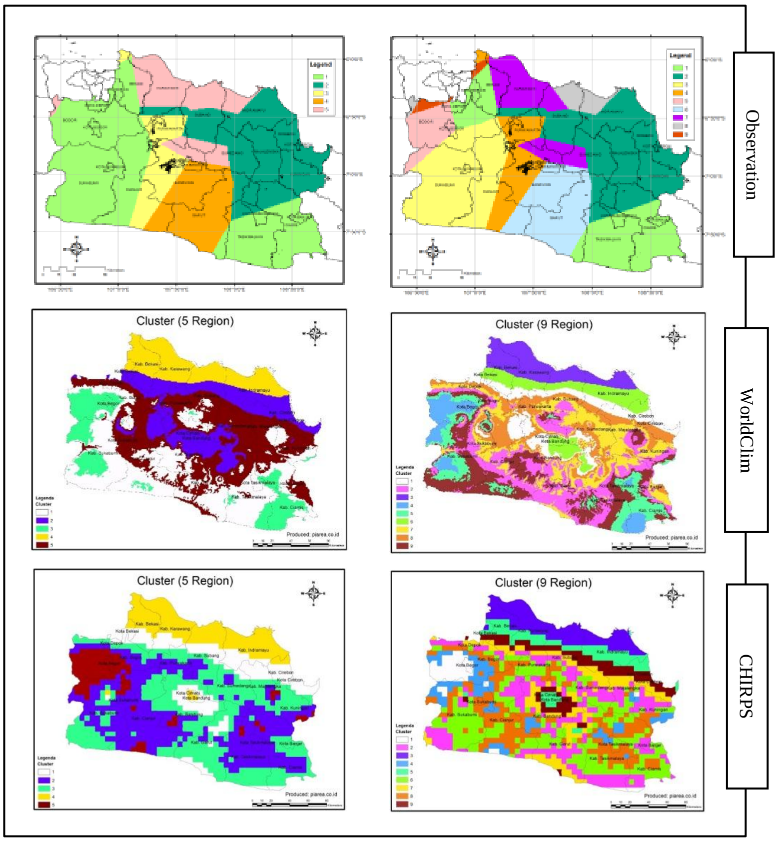

Figure 4. Climate regionalization for different data sources

Table 1. Climate characteristics of each climate group derived using hierarchical clustering technique applied to rainfall data of the 19-site observations

Group	Station	Characteristics
1	Atang Sanjaya Bogor, Cibinong, Tasikmalaya	High rainfall amount are in DJF and lower rainfall amount are in JJA whose monthly rainfall differences are small.
2	Cikumpai, Cirebon, Jatiwangi, Kalijati, Kuningan	Rainfall for the rainy season is similar to Group 1, but monthly rainfall for dry season is lower than Group 1.
3	Cipanas, Citeko	The wet season is in JFM and monthly rainfall is higher than that for Group 1 and Group 2. Dry season is in JJA.
4	Husein Sastranegara, Jatiluhur, Margahayu 2	Relatively lower monthly rainfall over a year than Group 1, 2, and 3. Dry season is in JJA.
5	Dramaga	Temporally, monthly rainfall is high throughout the year.
6	Geofisika Bandung	Higher monthly rainfall occurs in February, November and December.
7	Jatisari, Lembang, Sukamandi	The average monthly rainfall is considerably the lowest, compared to the other climate groups.
8	Pusakanegara	The longest period of dry season, compared to the other groups. Relatively high rainfall occurs in the beginning year.

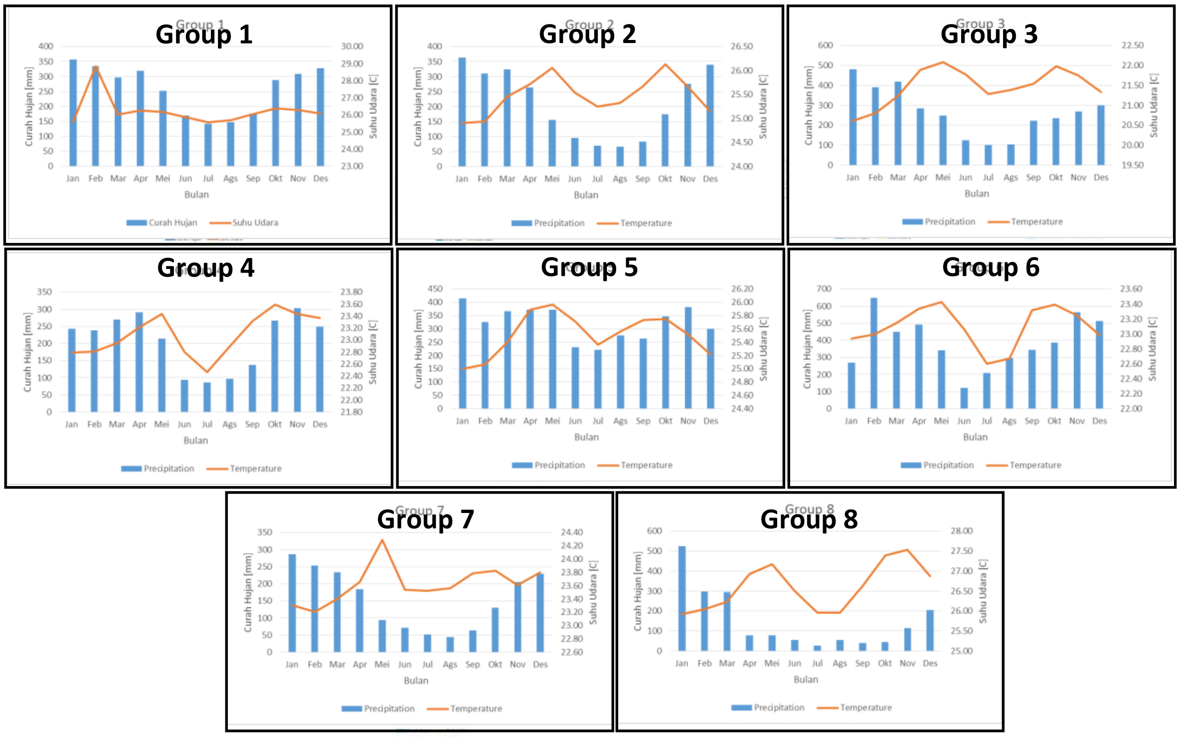

Figure 5. Monthly rainfall fluctuation for each climate group in the study region

5. Conclusion

Climate classification is one of essential tools in understanding spatial climate variation over a region, which can be further employed for planning decision on specific economic sector such as land-suitability for growing commodities. This research defines climate classification for West Java Indonesia using the three commonly used classification techniques (i.e, Koppen, Oldeman, and Schmidt Ferguson) and the climate regionalization method. The regionalization employed principal component analysis in combination with hierarchical clustering technique applied to monthly rainfall of site-observations and gridded climate data available for the study region, i.e., WorldClim and CHRIPS. The analysis revealed that the gridded climate data provide an alternative to perform climate classification when the site-observations are often limited. The climate classification applied to the gridded climate data exhibits a latitudinal variation of climate characteristics over the study region. The climate regionalization displays that the northern and southern areas of the region show distinct climate types; whereas, the central areas of the region show quite complex spatial variation, indicated the differences in climate types. The spatial variation of climate types may also in line with topographical condition of the region. Future works can further employ the regional climate classification to study land-climate suitable areas for many purposes such as distribution of agricultural commodities over crop production regions.

Acknowledgment

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